Temporal Sensitivity and MOVES Operation Modes – A Fundamental Design Deficiency

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Origin of Problem

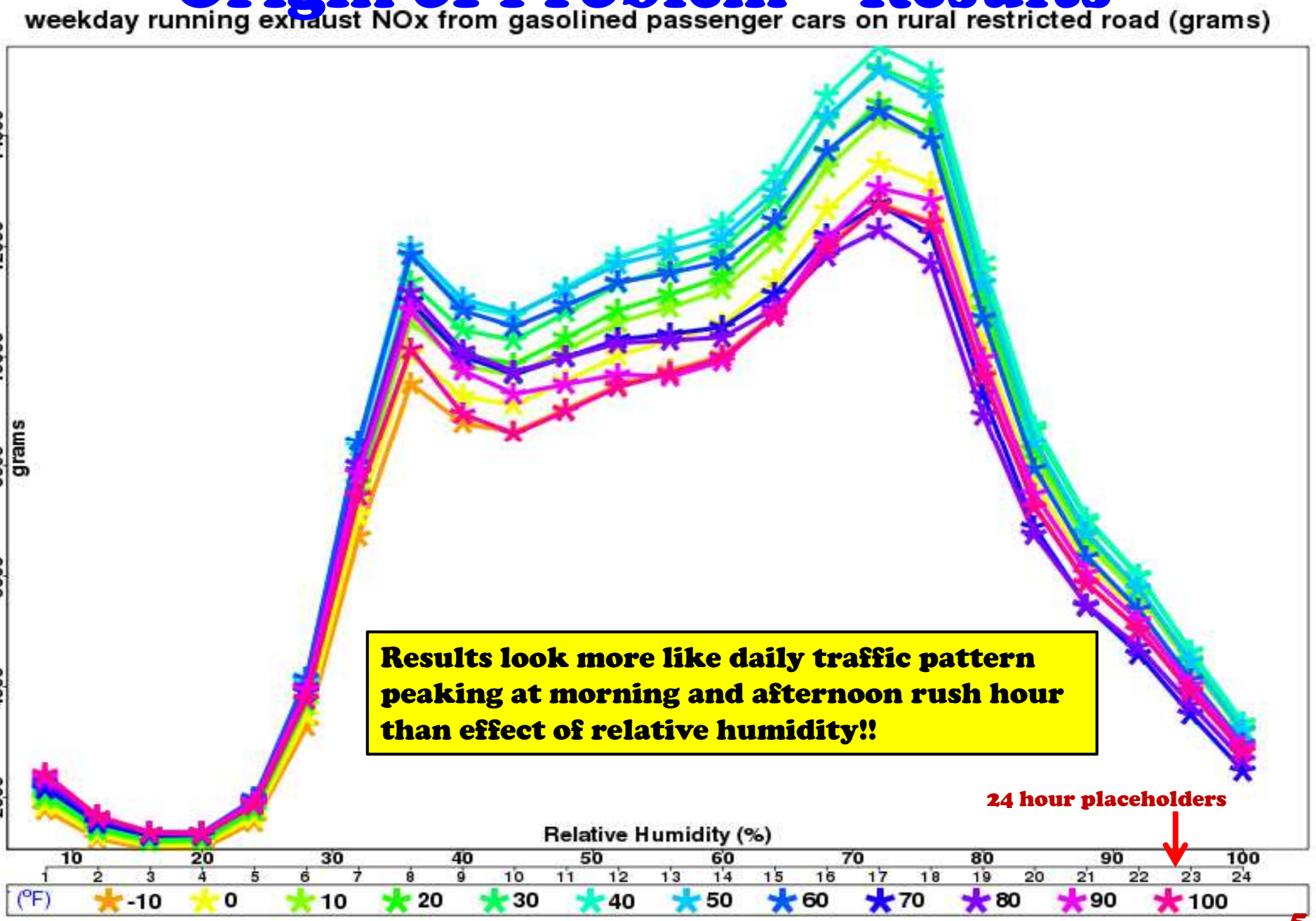
Origin of Problem
Motivation

- MOVES2010b-based SMOKE-MOVES cannot simulate relative humidity (assumed constant for a fuel month and for a representative county)
- How does relative humidity affect pollutants from mobile sources?
- Can the effect of relative humidity be quantified?
- MOVES2014 has fixed SCC flaws, allowing more robust modeling free of noise
- Conduct systematic sensitivity runs in MOVES inventory mode to examine the effect of relative humidity

Origin of Problem Sensitivity Settings

- 288 entries (24 hour * 12 month) in "annual" met file were used as placeholders for varying temperature and relative humidity
- 24 "hour" spots were filled with relative humidity from 8% to 100% with an increment of 4% (8%, 12%, 16%, etc)
- 12 "month" spots were filled with temperature from -10F to 100F with an increment of 10F (-10F, 0F, 10F, 20F, etc)
- Other inputs remained the same as those submitted to 2011NEI
- MOVES "annual" run in inventory mode was conducted for one county (Albemarle, VA) -- one runspec
- Hourly output, which should correspond to the placeholder RH/T combo, were queried for a source type, a road type, a process, and a weekday

Origin of Problem -- Results



Origin of Problem -- Summary

- The 288 placeholders were influenced by other inputs with temporal factors (for example, hourly vmt fractions)
- Other inputs with temporal factors could also have exerted unwanted influence (daily vmt fractions)
- In other words, other temporal inputs interfered with the design of the sensitivity analysis
- The effect of meteorology on pollutants was therefore not correctly isolated

Temporal Inputs and Temporal Study

So how can the sensitivity analysis be conducted correctly?

MOVES Temporal Inputs

Input	Naming Convention in MOVES Default Database	Temporal ID in Header	Resolution
average speed	avgspeeddistribution	hourDayID	day/hour
vmt allocation by hour	hourvmtfraction	dayID, hourID	day/hour
vmt allocation by day	dayvmtfraction	monthID, dayID	month/day
vmt allocation by month	monthvmtfraction	monthID	month
fuel supply	fuelsupply	monthGroupID	month
meteorology	none in default	monthID, hourID	month/hour

1. Other than met, five additional inputs involve temporal factors (hour, day, month)
2. Meteorology input is resolved at month and hour levels, missing dayID!

"Generic" Temporal Inputs

- **Create "generic" temporal inputs with equal fractions throughout:**

Input	Temporal ID in Header	Generic Numbers
avgspeeddistribution	hourDayID	0.0625 (1/16) for 16 speed bins for all hourDayID
hourvmtfraction	dayID, hourID	0.041667 (1/24) for 24 hourID by dayID
dayvmtfraction	monthID, dayID	0.2857 for dayID 2 and 0.7143 for dayID 5 for 12 monthID
monthvmtfraction	monthID	0.083333 (1/12) for 12 monthID
fuelsupply	monthGroupID	equal marketShare for 12 monthGroupID
meteorology	monthID, hourID	60% for 24 "hour" spots 80F for 12 "month" spots

- **All 288 spots in met file have RH=60% and T=80F**

MOVES Temporal Study Approach

- Using the same met file with identical RH/T (60%/80F), a series of "annual" inventory runs using MOVES2014 were conducted to examine the influence exerted by temporal inputs
- Starting with no "generic", each successive MOVES run included one more "generic" temporal input than the previous run:

MOVES Run	Generic Files Used
(0) no generic	none
(1) one generic	hourvmtfraction
(2) two generics	hourvmtfraction + avgspeeddistribution
(3) three generics	hourvmtfraction + avgspeeddistribution + monthvmtfraction
(4) four generics	hourvmtfraction + avgspeeddistribution + monthvmtfraction + dayvmtfraction
(5) five generics	hourvmtfraction + avgspeeddistribution + monthvmtfraction + dayvmtfraction + fuelsupply

- GOAL:

To have identical output for all hours and months so that a correct set of generic files can be identified and used in future sensitivity study to isolate the effect of meteorology

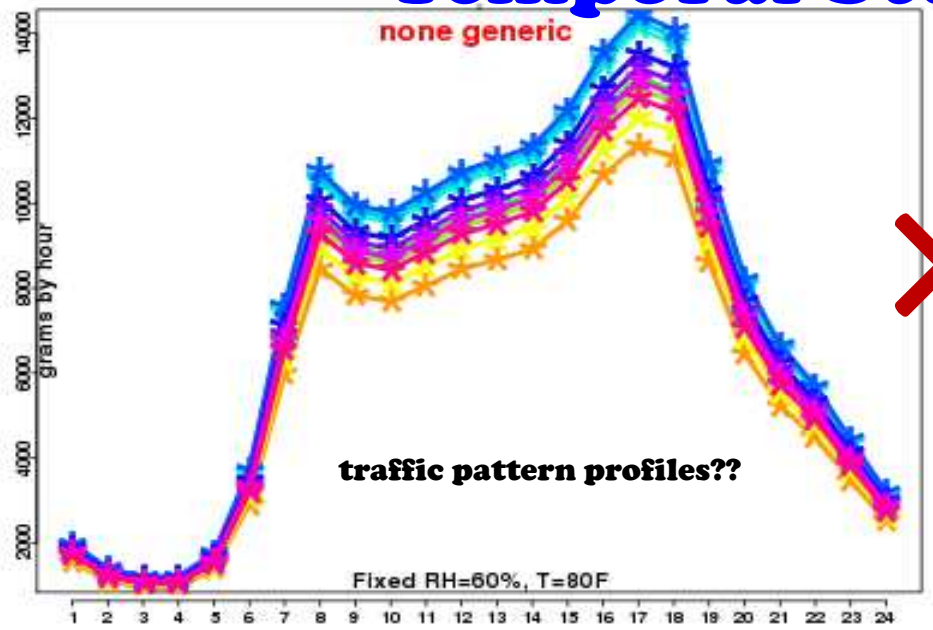
Query Output Analyses

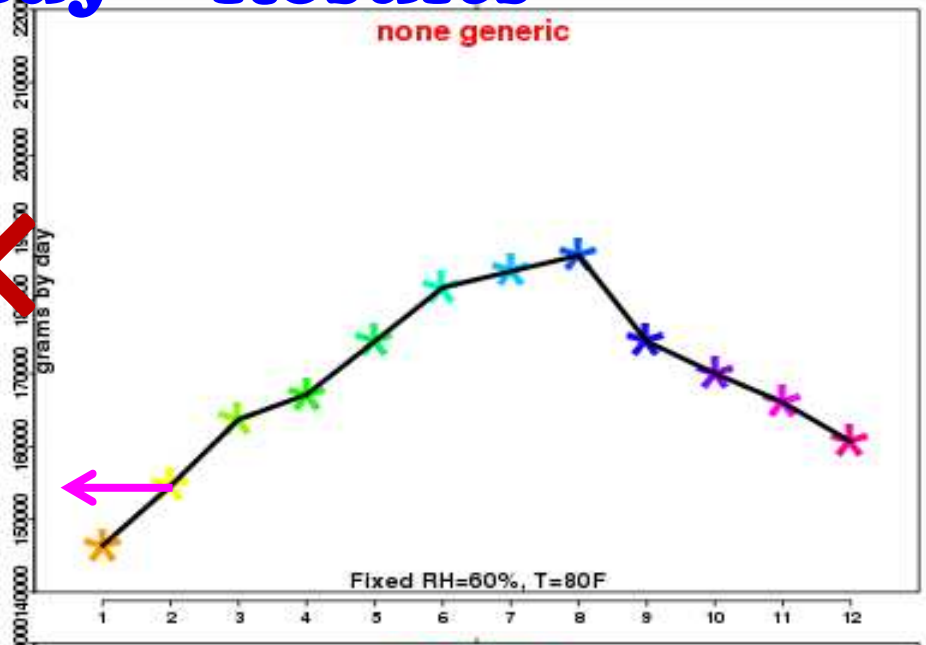
- Hourly outputs were pulled and plotted directly (left panel)
- 24 hourly numbers were summed by month for a "daily" total for the month (solid line, left axis of the right panel)

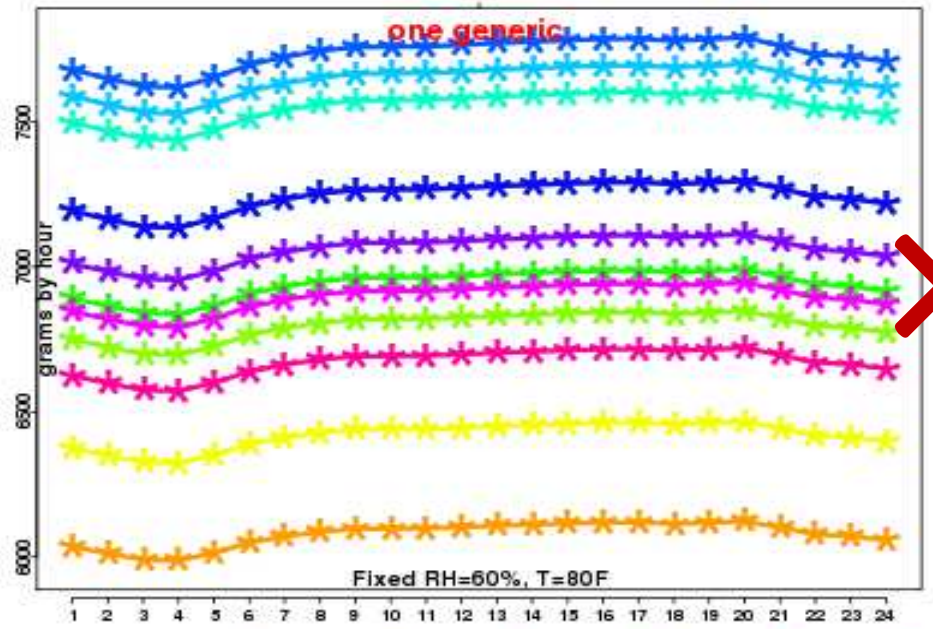
Due to "equal" model setup, the two categories should yield horizontal straight lines to correctly isolate meteorological effect

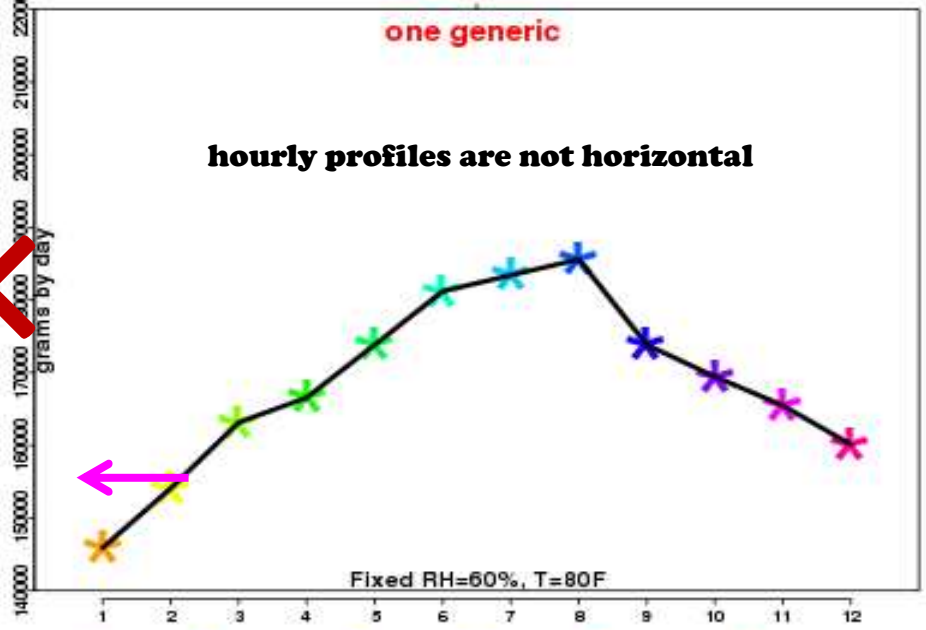
Focus: weekday (dayID=5): only weekday numbers were extracted
gasoline passenger cars (fuelTypeID=1, sourceTypeID=21)
rural restricted access (roadTypeID=2)
running exhaust (processID=1)

Temporal Study -- Results



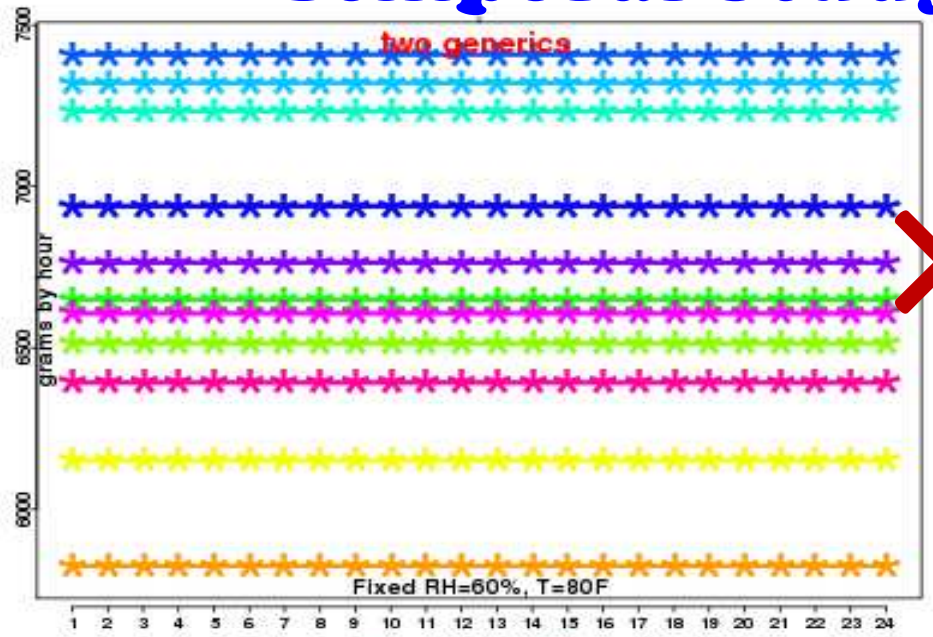


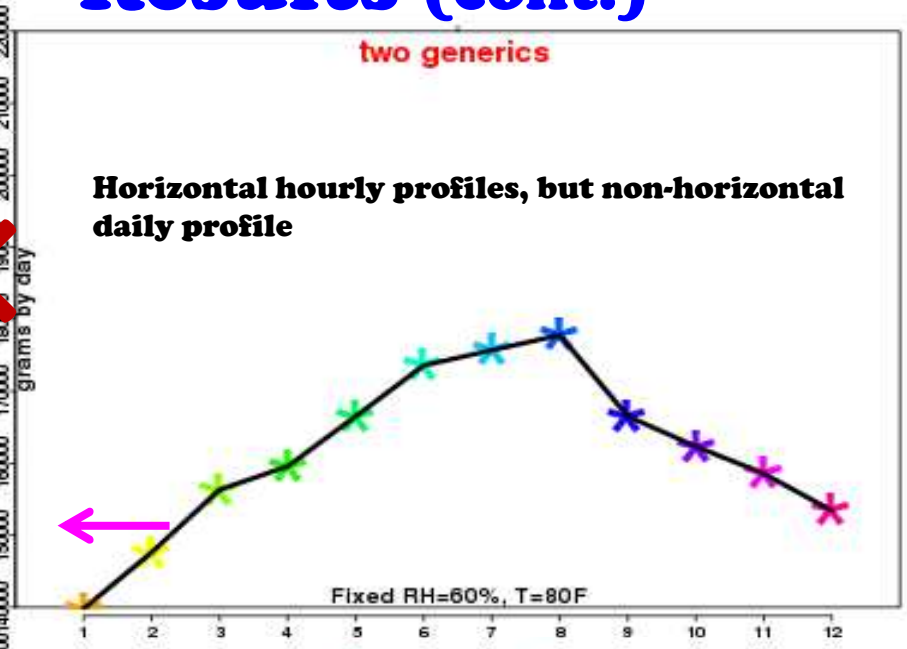




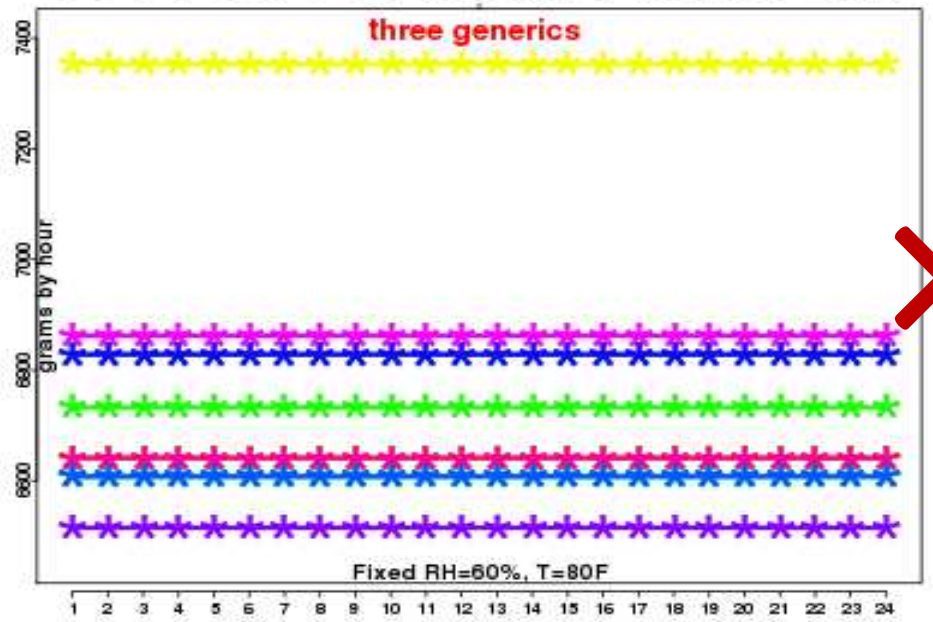
month block mon1 mon2 mon3 mon4 mon5 mon6 mon7 mon8 mon9 mon10 mon11 mon12

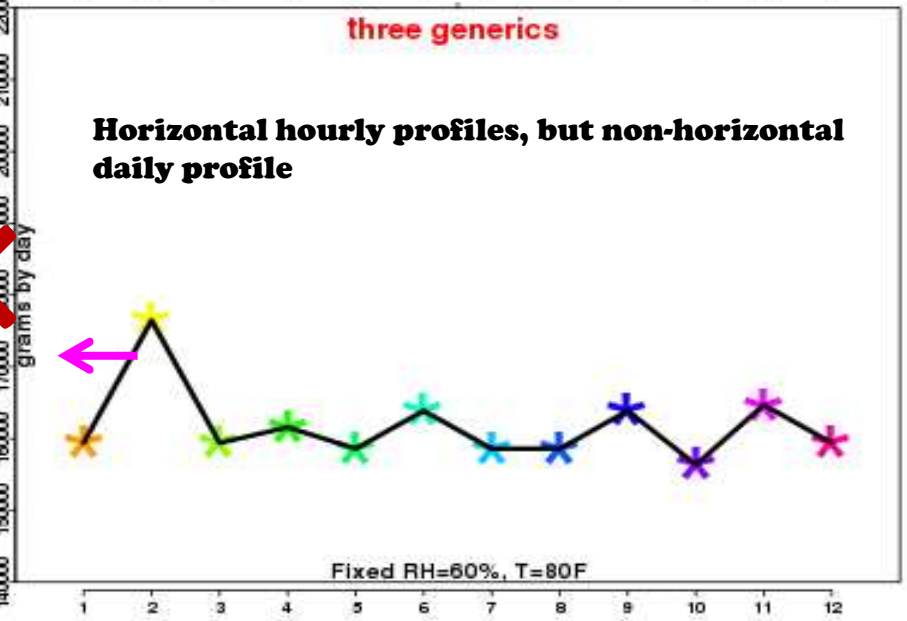
Temporal Study -- Results (cont.)





Horizontal hourly profiles, but non-horizontal daily profile

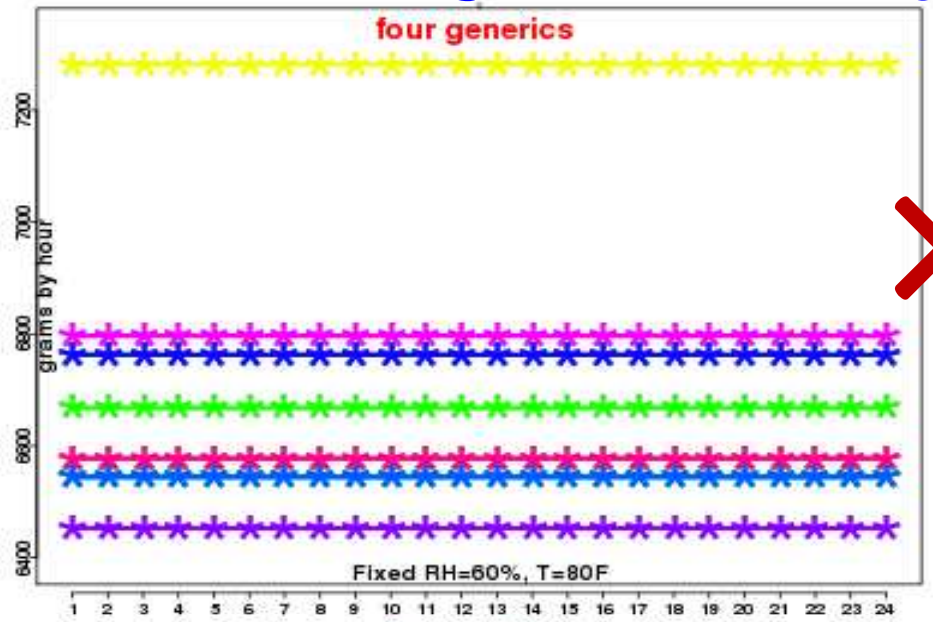


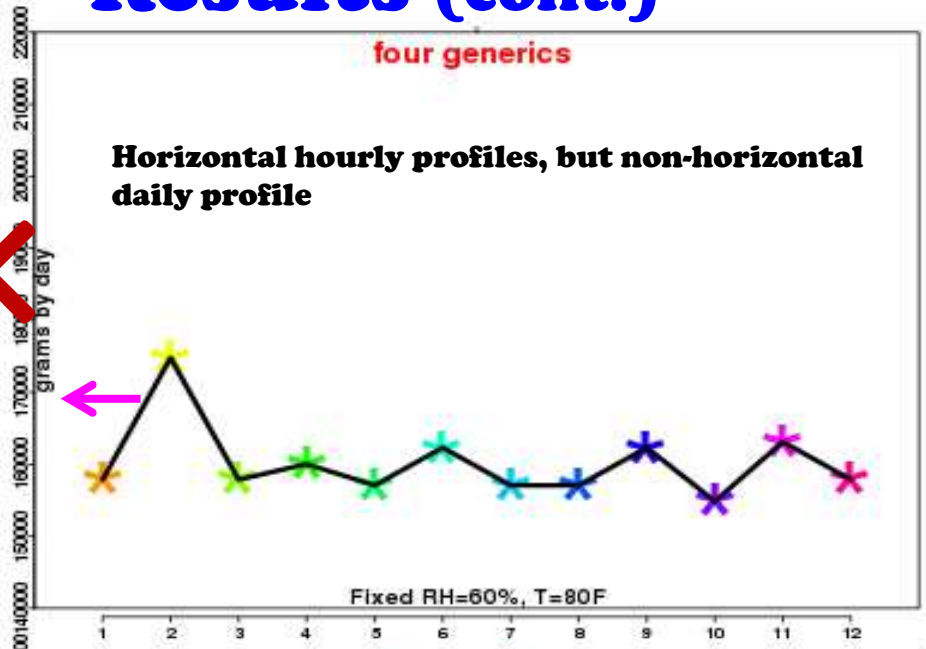


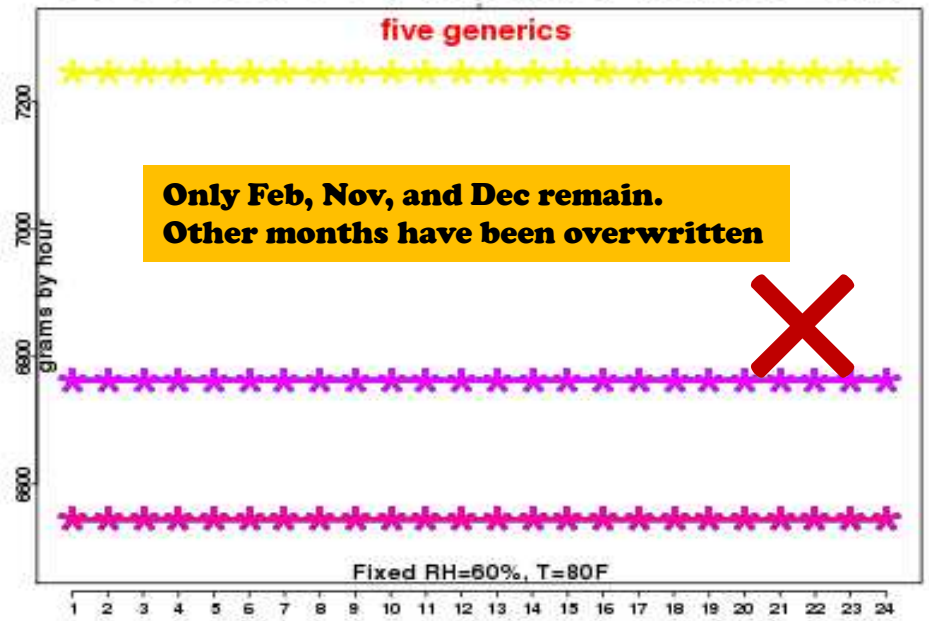
Horizontal hourly profiles, but non-horizontal daily profile

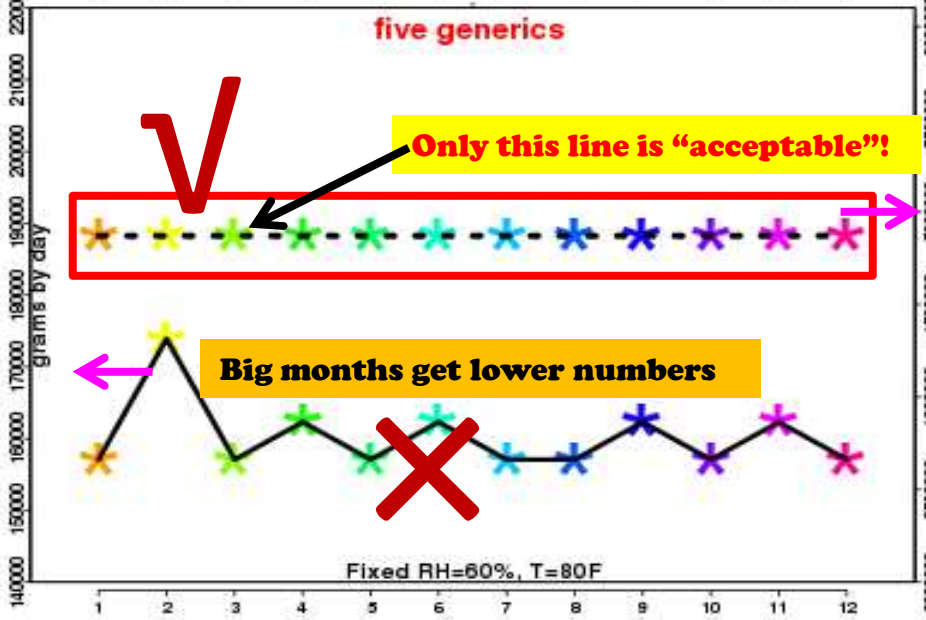
month block mon1 mon2 mon3 mon4 mon5 mon6 mon7 mon8 mon9 mon10 mon11 mon12

Temporal Study -- Results (cont.)









month block mon1 mon2 mon3 mon4 mon5 mon6 mon7 mon8 mon9 mon10 mon11 mon12

Temporal Study -- Summary

- Output cannot be made identical unless it is multiplied by the number of days of the month (dash line, right axis of the bottom right panel)
- Hourly output is hard-coded internally in MOVES and is a result of VMT temporalization:

  hourly emissions = (monthly emissions/30, 31, or 28) * dayvmtfraction * hourvmtfraction

All things being equal, hourly numbers in February are inherently the highest!

- The hard-coded temporalization is contradictory to the sensitivity design (i.e., placeholder practice is invalid)
- "Annual" inventory mode cannot be used in temporal sensitivity because the effect of meteorology cannot be correctly isolated, even with "generic" adjustments to five temporal inputs

EPA please comment

Options for Temporal Sensitivity

- Monthly inventory mode
- Emission rate mode

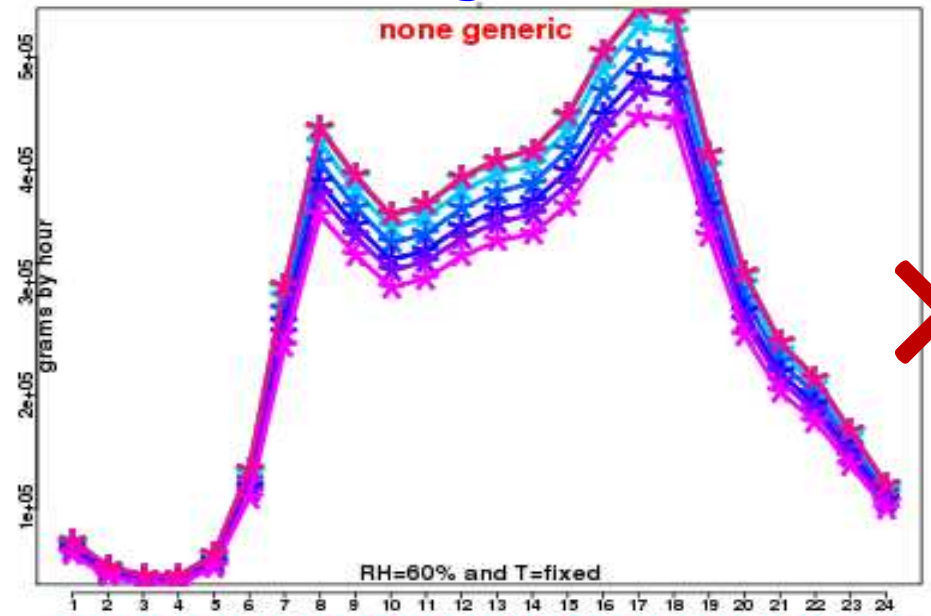
Temporal Sensitivity – Option 1 Monthly Inventory Approach

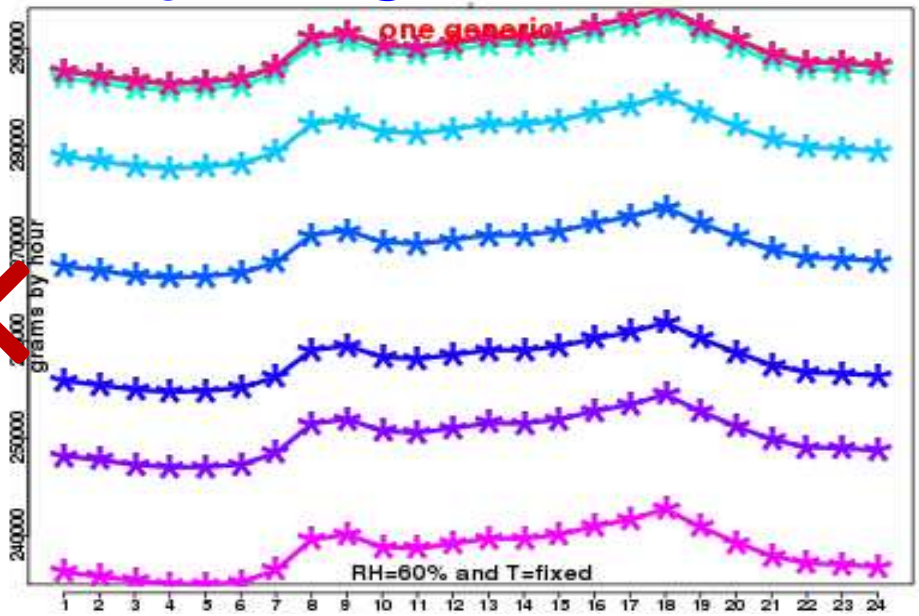
- Instead of an annual run, a series of "monthly" (e.x., monthID=7) MOVES inventory runs were conducted as a first option
- Each of the month7 runs were filled with a constant relative humidity of 60% and a fixed temperature, ranging from -10F to 100F with an increment of 10F (-10F, 0F, 10F, etc), in 24 hour spots for a total of 12 month7 runs
- Starting with no "generic", each successive MOVES run included one more "generic" temporal input than the previous run

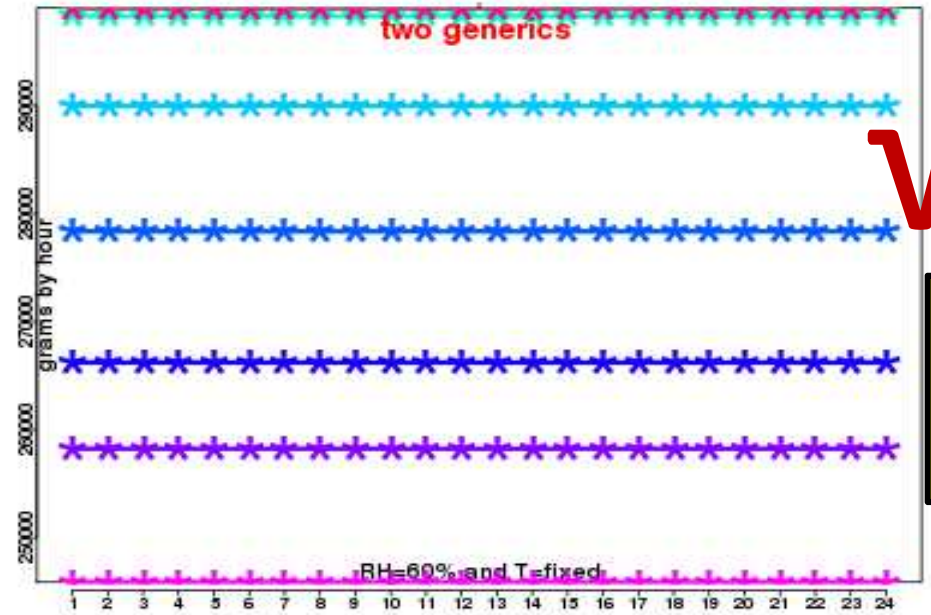
- GOAL:

  To have identical output for all hours in each month7 run so that a correct set of generic files can be identified to isolate the effect of meteorology

Temporal Sensitivity – Option1

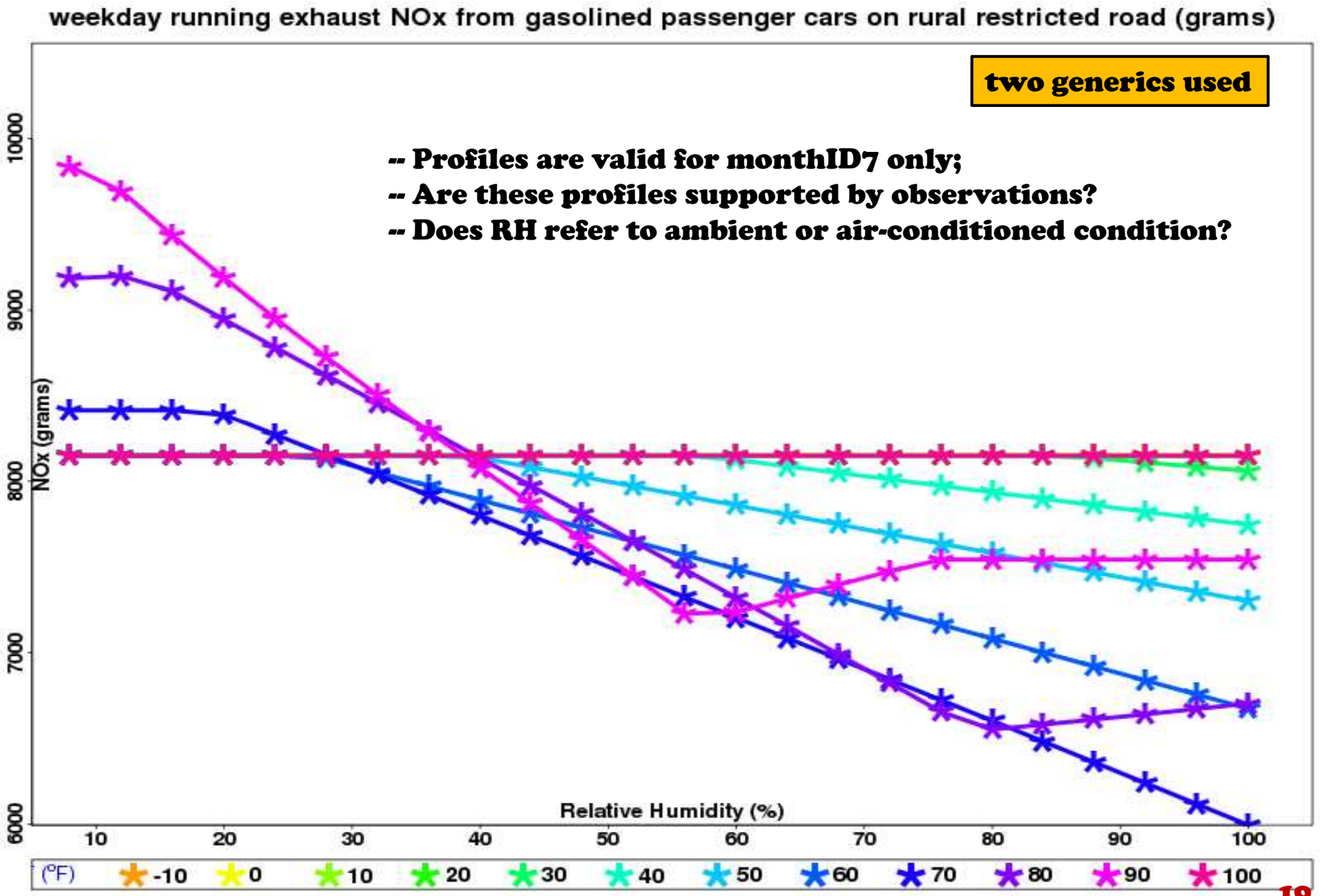




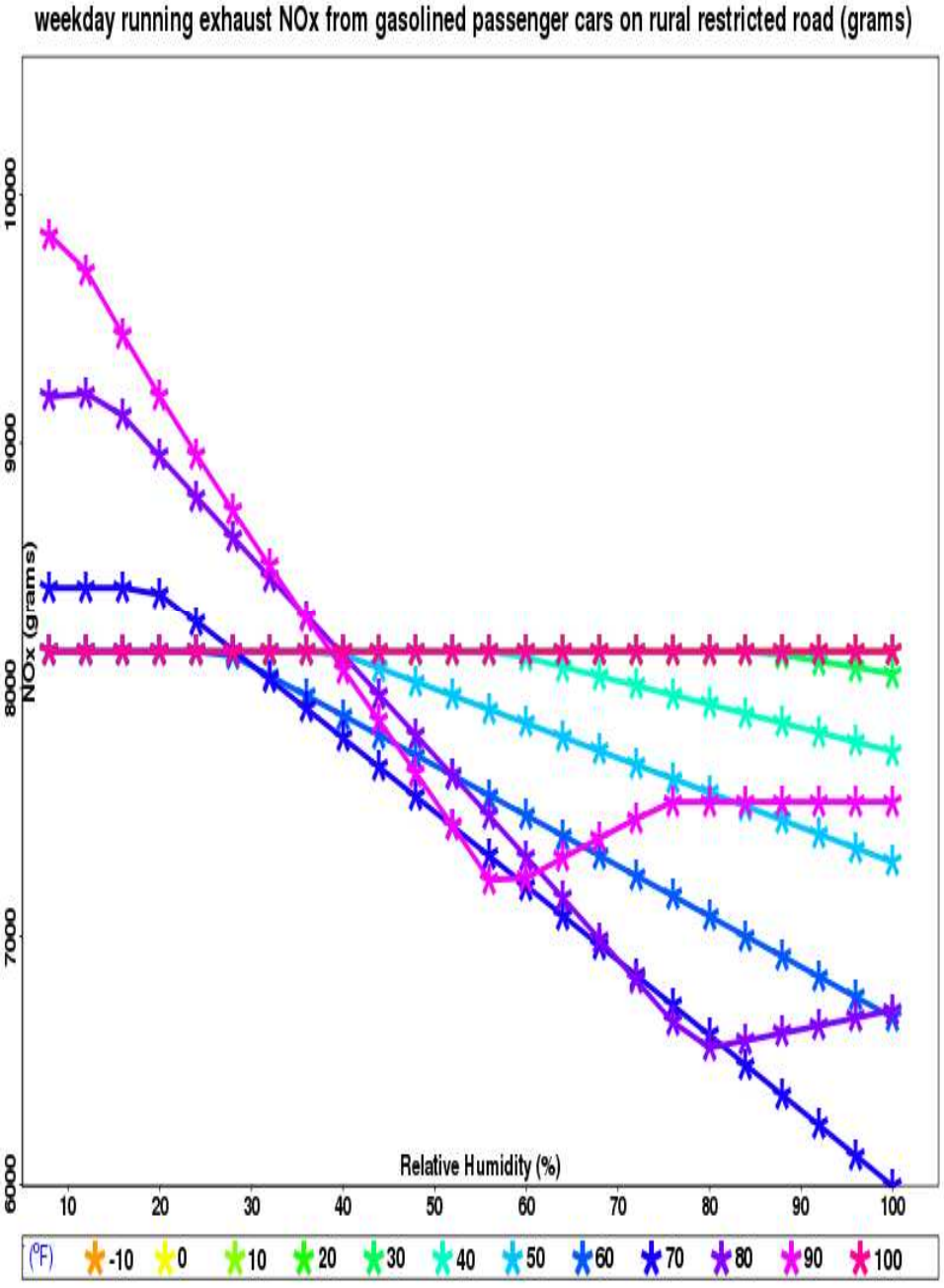


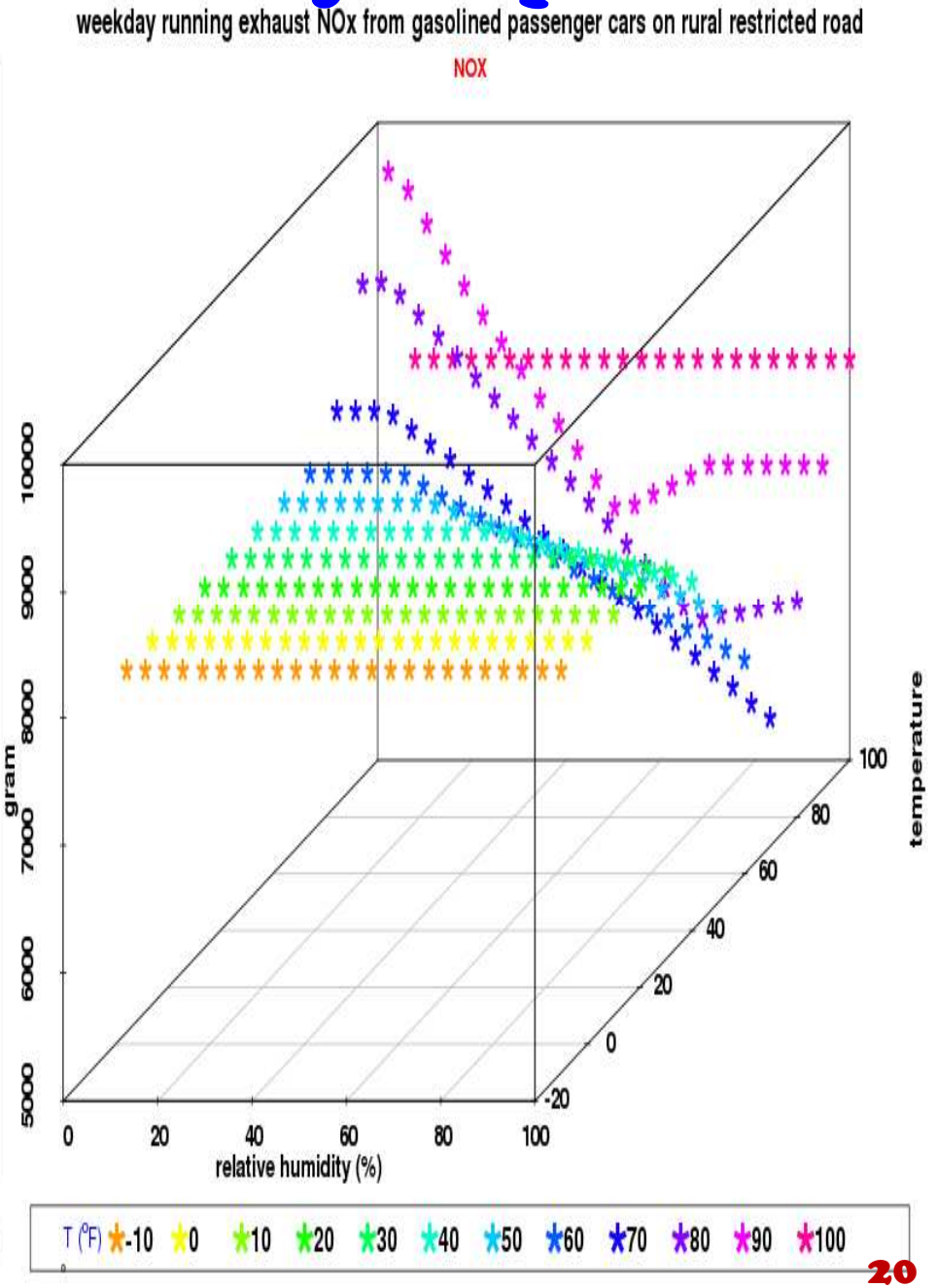
Unlike annual run, a month7 run needs only two generics to yield a horizontal line:
(1) hourvmtfraction, and
(2) avgspeeddistribution

Effect of Relative Humidity – Option1



Effect of Relative Humidity – Option1

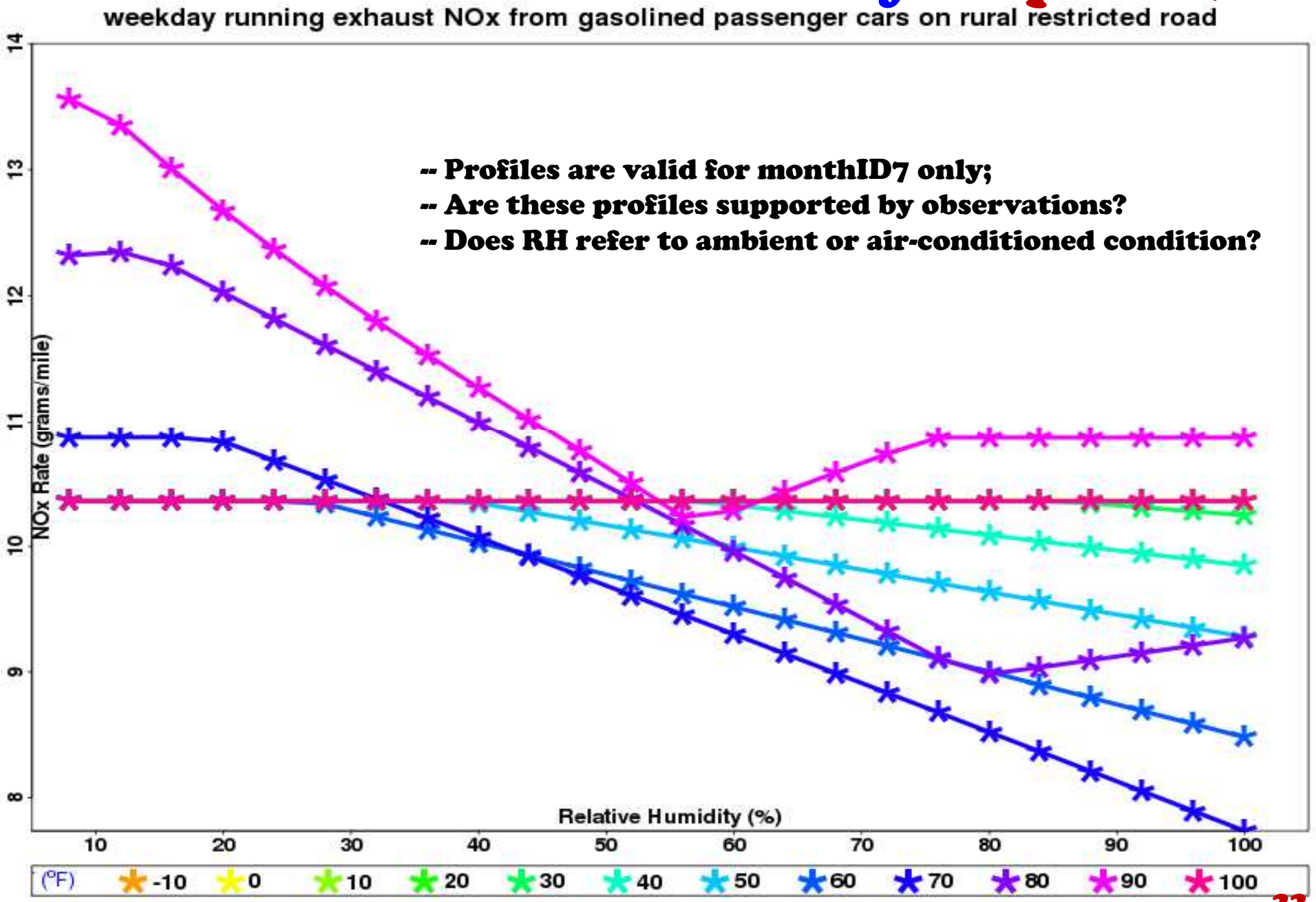




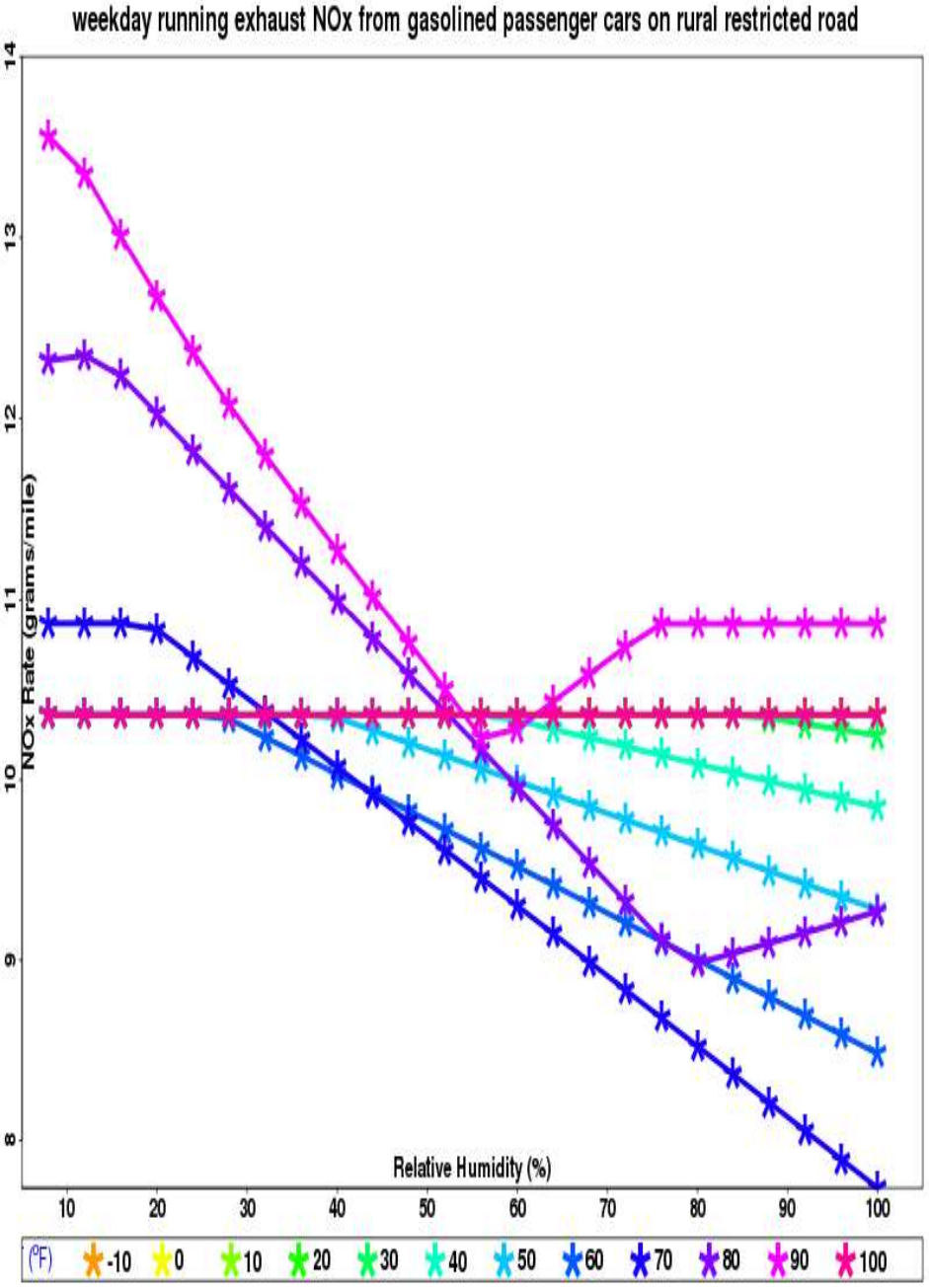
Temporal Sensitivity – Option 2 Emission Rate Approach

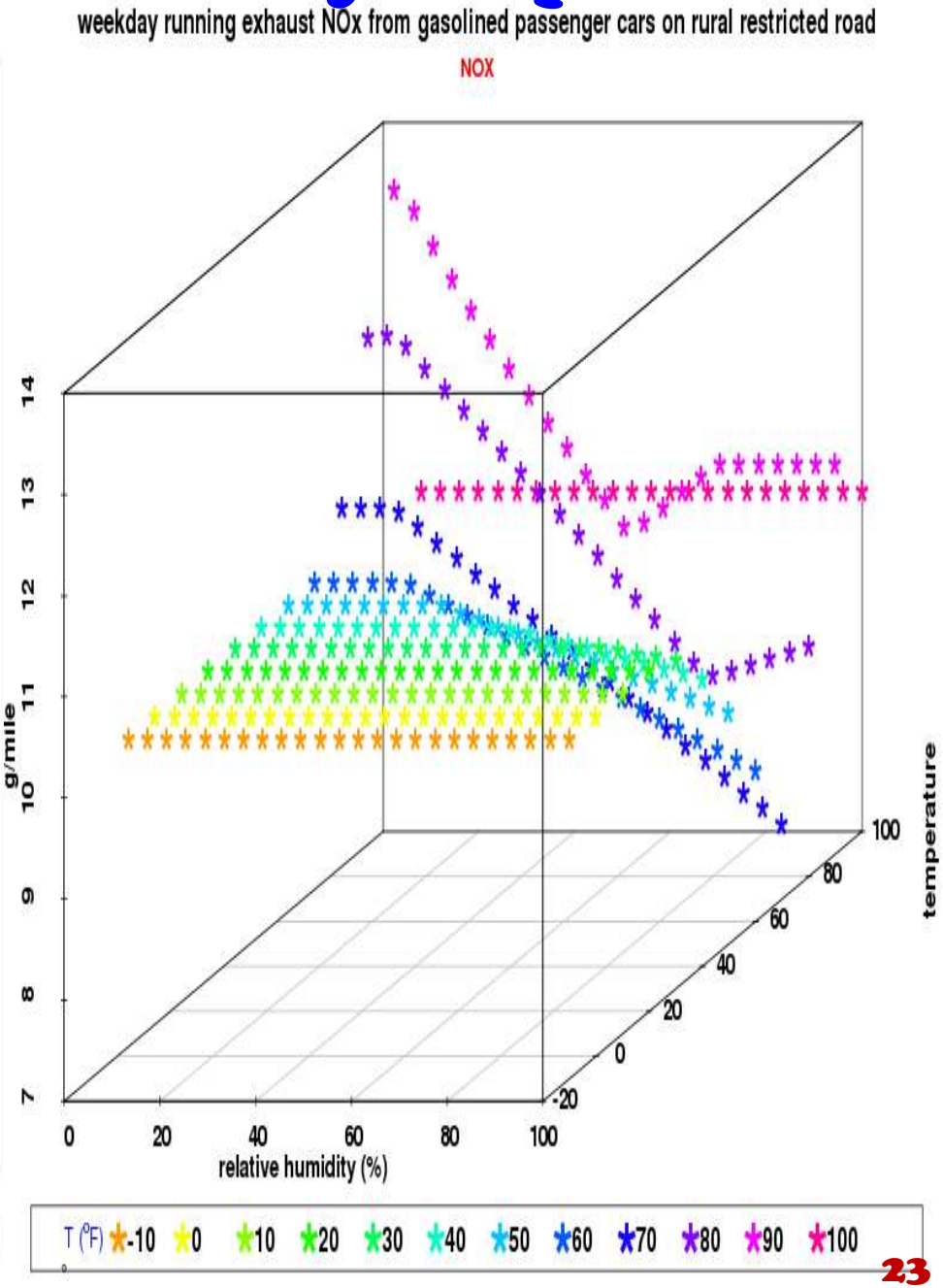
- Similar to option 1, a series of monthID=7 MOVES runs were conducted as a second option
- 24 "hour" spots were filled with relative humidity from 8% to 100% with an increment of 4% (8%, 12%, 16%, etc)
- Each of 12 "month" runs was filled with a constant temperature from -10F to 100F with an increment of 10F (-10F, 0F, 10F, 20F, etc)
- Original 2011NEI MOVES inputs. No generic inputs were applied
- RATE mode was requested in runspecs

Effect of Relative Humidity – Option2



Effect of Relative Humidity – Option2

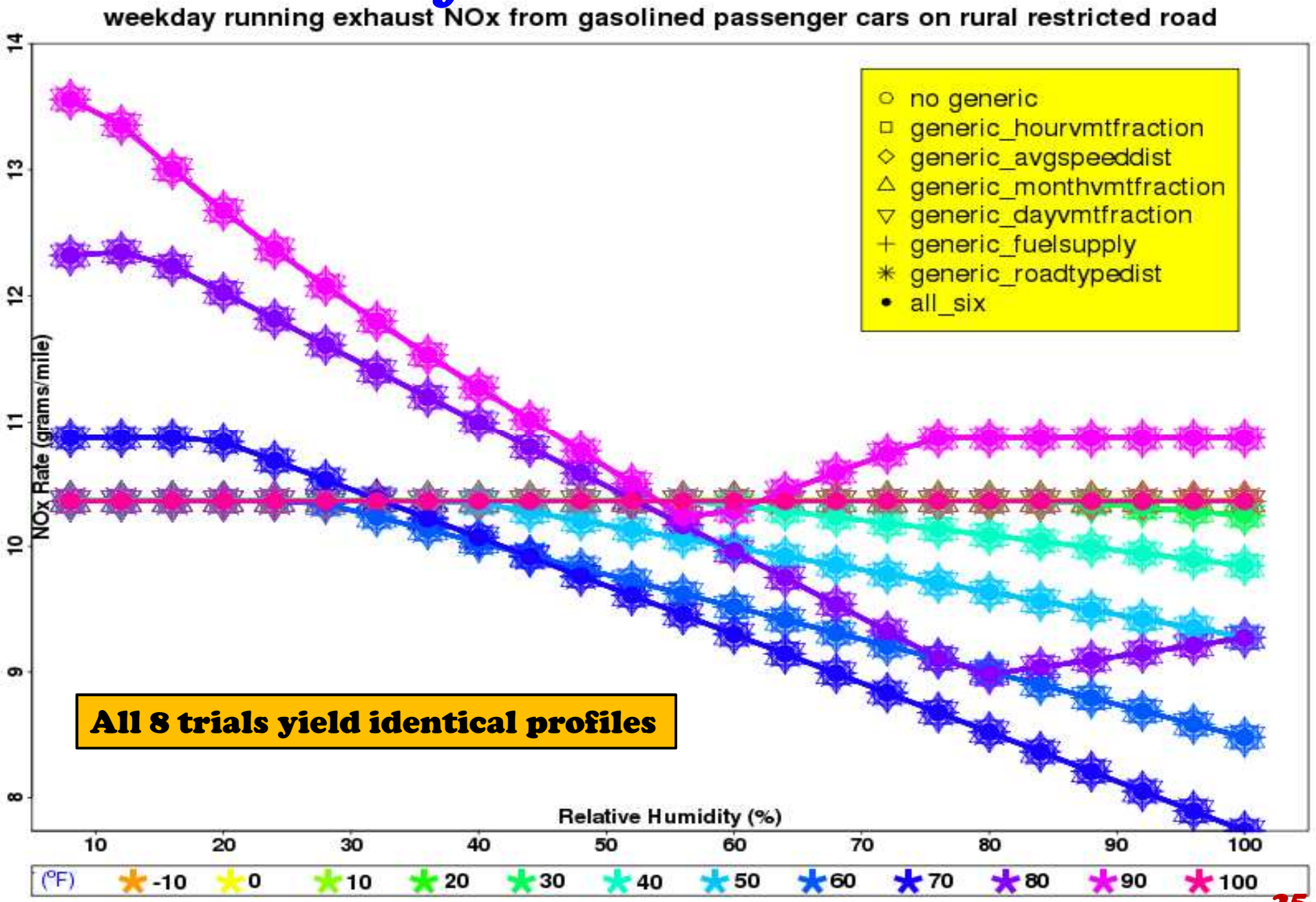




Dummy Trials for Rate Mode

- **Motivation: Rate is expressed as mass/mile, so inputs with temporal factors play no role in calculations**
- **Approach: successive MOVES runs in rate mode, each with a different "generic" file**
- **Including "no generic" and "all generics" (six generic files), a total of eight runs were conducted**

Dummy Trials for Rate Mode



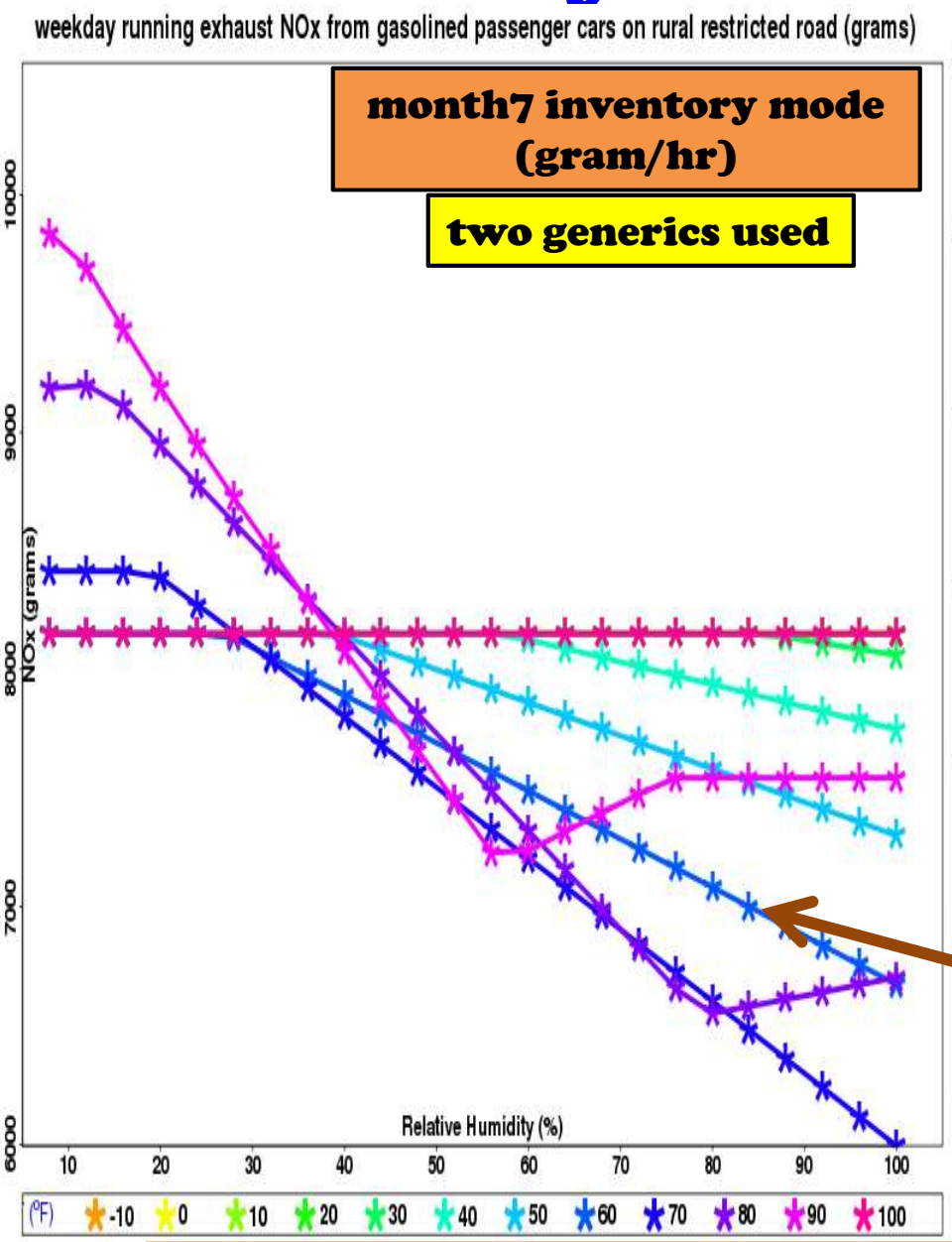
All 8 trials yield identical profiles

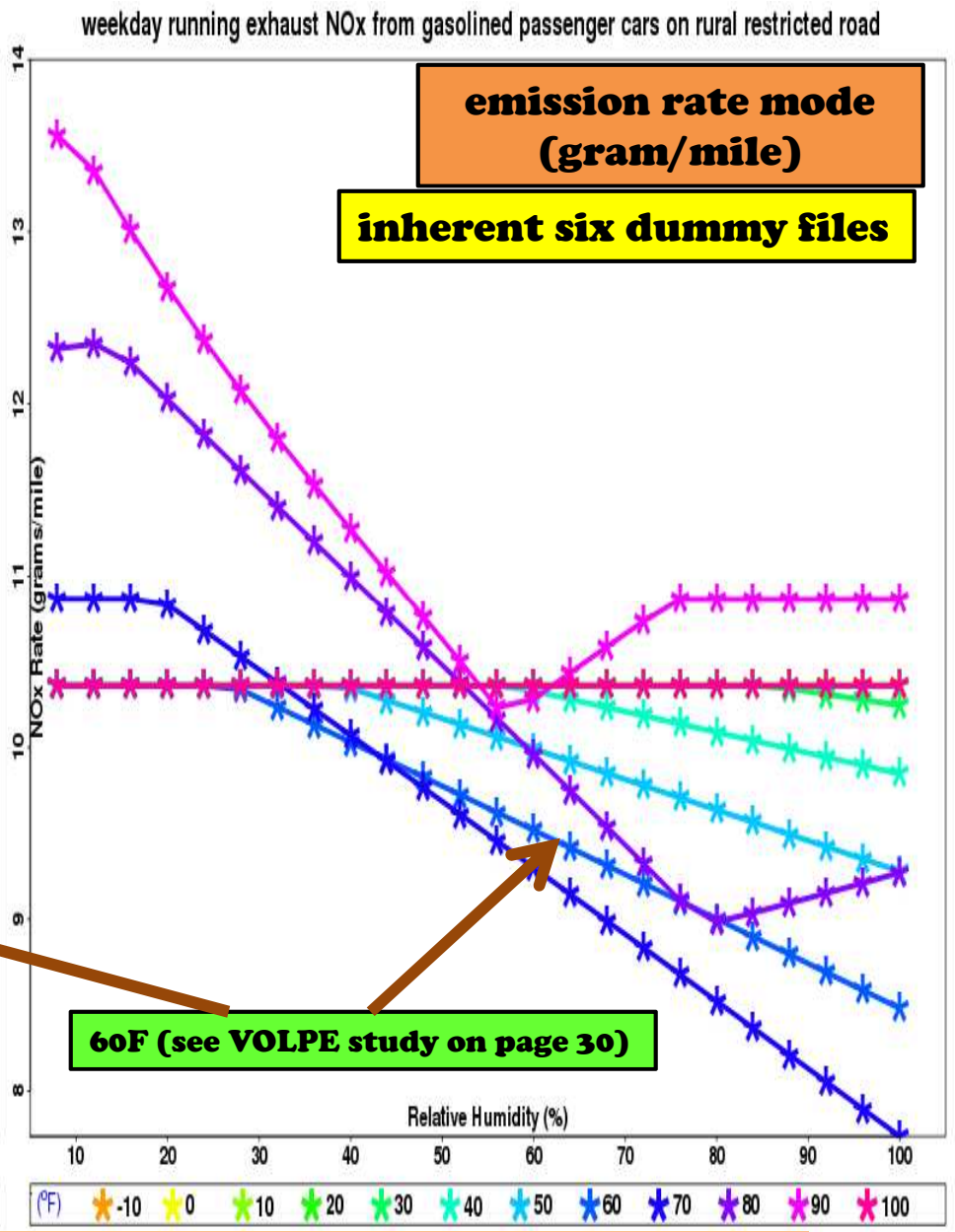
Dummy for Emission Rate Mode

- Six files are considered dummy in emission rate mode:
  - avgspeeddistribution
  - hourvmtfraction
  - dayvmtfraction
  - monthvmtfraction
  - fuelsupply (not really a dummy, but for a particular month)
  - roadtypedistribution (to prevent mismatch with avg speed)
- Emission rates are identical irrespective of the dummy files
- Except roadtypedistribution, the other five files are the same ones used in the “annual” temporal study described in this presentation

Comparisons

Inventory Mode versus Rate Mode





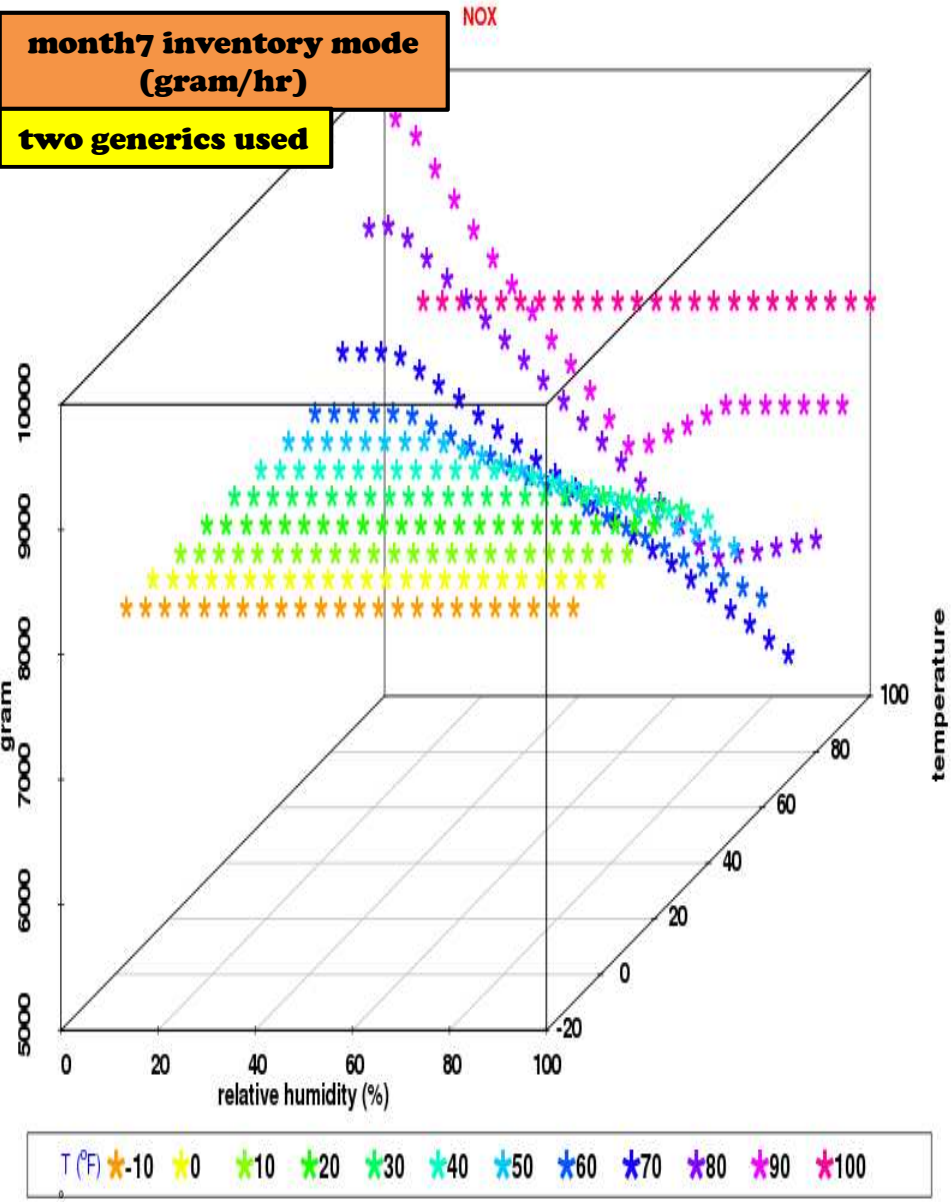
60F (see VOLPE study on page 30)

Profiles in two modes look similar. It's not clear why higher RH/T in two modes are inconsistent

Inventory Mode versus Rate Mode

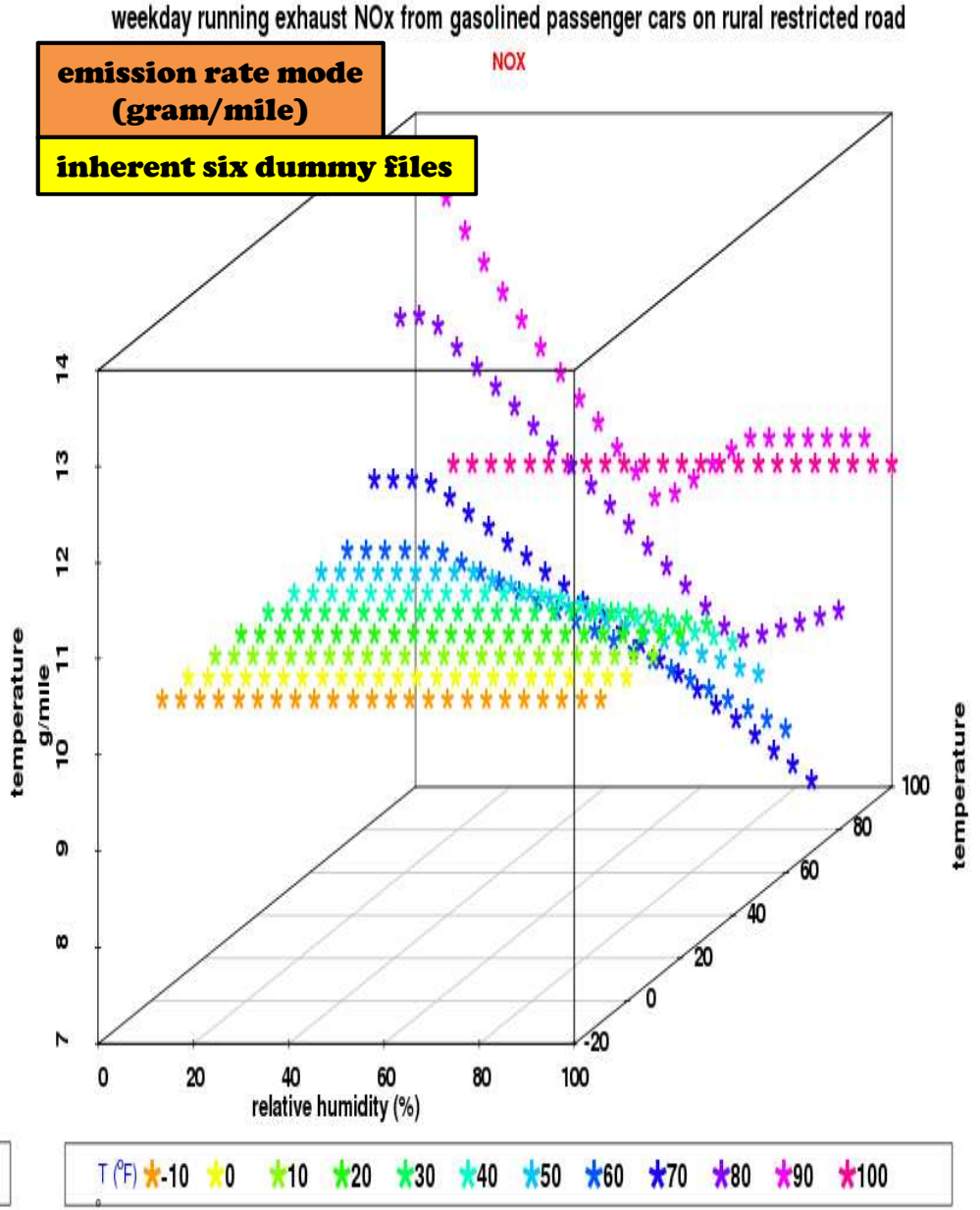
month7 inventory mode (gram/hr)

two generics used



emission rate mode (gram/mile)

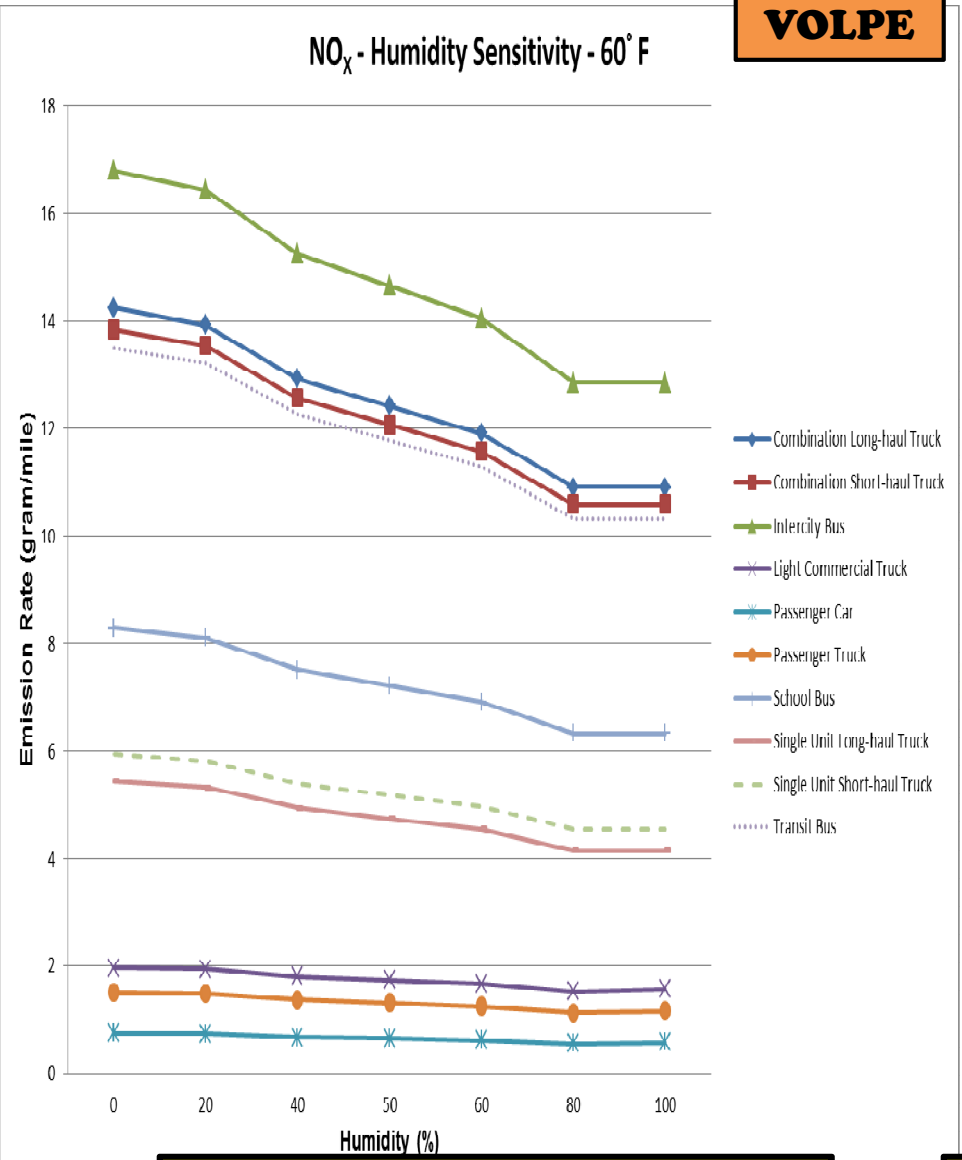
inherent six dummy files



Profiles in two modes look similar. It's not clear why higher RH/T in two modes are inconsistent

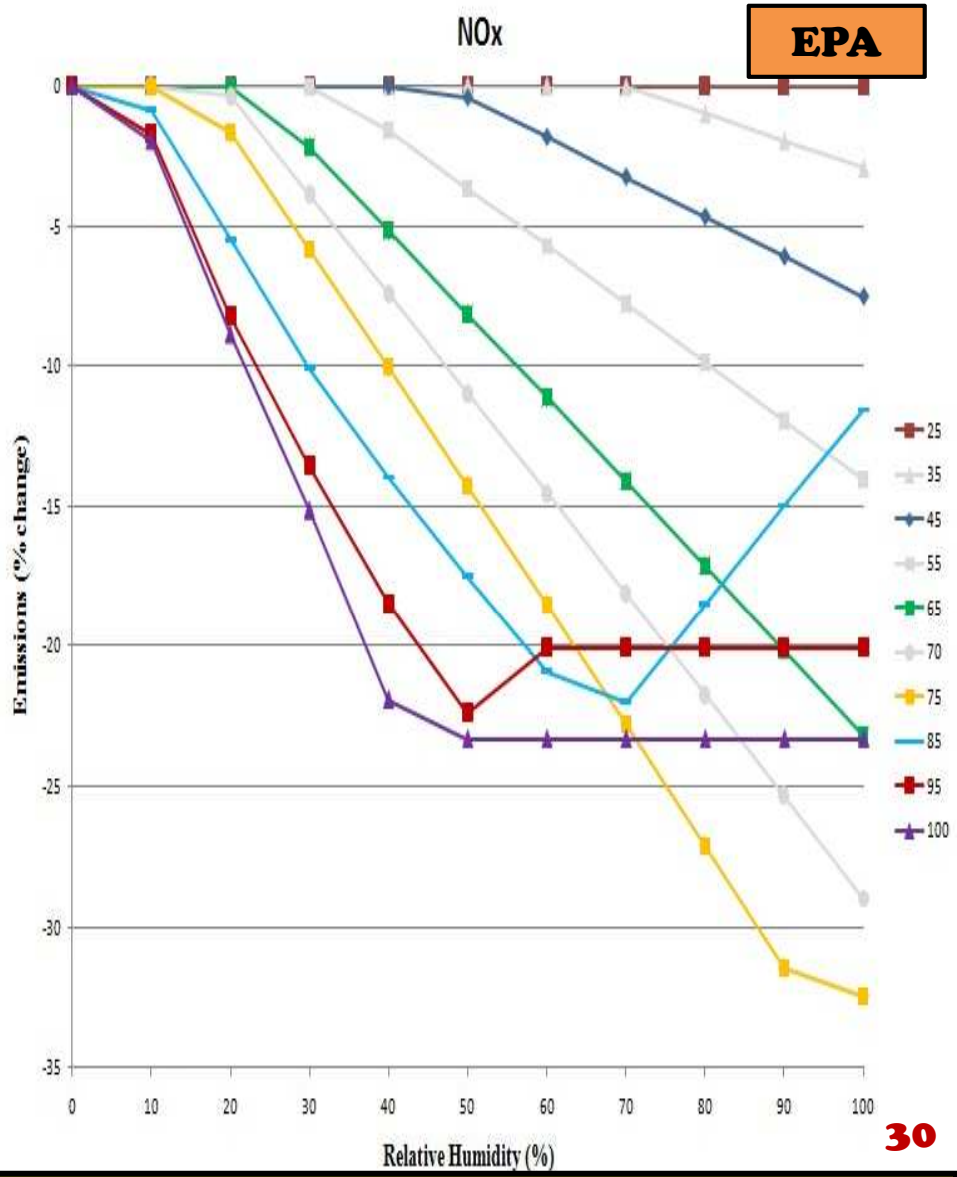
Other Studies on RH

VOLPE



Comments:
-- rate mode (sound approach)
-- have all vehicles types, but 60F only

EPA



Comments:
-- differences in inventory mode
-- overall shapes, lower RH inconsistent with rate mode

Summary and Conclusions

SESARM Modeling Plans

- Run MOVES in inventory mode with WRF/MCIP inputs
- Annual MOVES runs in inventory mode with hourly met observations for all non-attainment counties
- Even if hourly data are supplied, it appears MOVES still operates by month and internally temporalizes monthly VMT to hourly outputs

  e.x., inventory mode with hourly met observations would yield incorrect or unintended results
- It's not clear how this will affect modeling plans. More study is needed

Summary and Conclusion

- Temporal resolution in inventory mode is always by month
- Any attempts to increase resolution (to day or hour) are inconsistent with or contradictory to MOVES original design
- Inventory mode cannot be used in sensitivity modeling unless accompanied by two generic inputs in a monthly approach to correctly isolate temporal factors
- Sensitivity involving temporal factors is best achieved by emission rate mode, which inherently assumes some dummy files
- Findings in this study are universal and can be applied to other sensitivity modeling, not just relative humidity
- The most accurate approach for developing a regional mobile source inventory is rate mode (similar to SMOKE-MOVES) but using each individual county for each month

"Low" SMOKE-MOVES resolution: representative county and fuel month

Summary and Conclusion (cont.)

- The role of meteorology inputs in overall MOVES process is unknown
- It is important that EPA release documents detailing how MOVES estimate emissions internally. A flowchart will be very helpful

Acknowledgements

- Virginia DEQ is partnered with Advanced Research Computing (ARC) at Virginia Tech which provides computing resources that have contributed to this study
- Thanks to Brian Marshall of ARC for his technical support of MOVES and MySQL
- URL: http://www.arc.vt.edu